TECHNICAL MEMORANDUMS

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 1019

STRENGTH TESTS ON HULLS AND FLOATS

By K. Matthaes

Jahrbuch 1938 der Deutschen Luftfahrtforschung

Washington
June 1942

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The present report deals with strength tests on hulls and floats intended in part for the collection of construction data for the design of these components and in part for the stress analysis of the finished hulls and floats.

INTRODUCTION

1. Procedure of Load Application in the Strength Test

The experimental procedure and method of loading on floats and hulls is theoretically the same as in all other static tests. Of the different possibilities of load application, the use of oil pressure cylinders has proved to be the best. Weights or spindles are employed more rarely and then only as an adjunct.

The loading of ribs and other structural parts by rows of oil-pressure cylinders has been standard practice in the E. Heinkel airplane factory since 1930 and continuously improved since then. The oil pressure is supplied by high output Bosch pumps. The pressure distribution is manipulated by special control valves, the pressure itself being recorded with micromanometers and towing indicators. The instruments are combined into portable units (fig. 1a). The manometers are connected with the pressure cylinders by separate lines in order to prevent the pressure loss in the lines from being included in the measurement. This applies to all but the very small pressure cylinders of 5 square centimeters area.

Recently the test method has been further improved by effecting the pressure distribution to the different oil-pressure cylinders by an automatic control, which insures automatic adjustment of the required pressure ratio independent of the state of loading (fig. 1b).

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*"Festigkeitsversuche an Schwimmwerken." Jahrbuch 1938 der deutschen Luftfahrtforschung, pp. I 342 - I 347.

The same procedure employed on wing structures is followed on floats and hulls, that is, the parts are first tested separately and then the strength of the assembly is tested as a whole. As a result, three different test problems are generally involved.

1. Testing of float frames

2. Investigation of float body

3. Investigation of flotation gear or of the whole float system

The tests described hereinafter relate to float systems for groups I and II. Group I involves aircraft principally destined for take-off and landing in calm waters, group II for take-off and landing on waves.

As ultimate load for the float system the 1.55 times safe load is specified in all cases.

II. Experiments with Float Frames

For the proportions of the frames the bottom pressure is decisive. In the loading of the frames allowance can be made for the fact that a part of the bottom pressure is directly transmitted (from the skin) to keel and chine strip, thus giving a pressure distribution as indicated in figure 2a. Experimentally a uniformly distributed bottom pressure equal to the assumed highest bottom pressure is applied, thus affording a margin of safety (fig. 2b).

The frames are tested as in the rib failure tests on the test table (fig. 3). The frame is fitted with a cover strip of from 100 to 150 millimeters width. (Under certain circumstances the tip-forming strip is strengthened at the inside border by a riveted section in order to prevent premature buckling, since the conditions in the test are much more severe than in actual service.) The bottom pressure is applied by oil pressure cylinders of 5 square centimeters area. To insure uniform distribution of the pressure a 10 millimeters thick felt strip is placed on top of the frame and supported by tapered wood blocks against which the plungers of the oil-pressure cylinder press (fig. 4). The bottom pressure is transmitted from the frame to the skin. The distribution approximately corresponds to the curve of the transverse force under bending stress of the float. The transverse force is divided conformably to the shear distribution into several concentrated forces (fig. 5) which are applied tangentially at the frame circumference. These forces form the reaction forces to the bottom pressure at the frame. They are applied as tensile forces by means of tension straps or wire ropes, the forces (at either side of the frame) applied on the side walls of the frame at small angles being suitably combined to form a concentrated force by a system of levers. The other forces (applied closer to the top) forming larger angles, are applied individually by small oil-pressure cylinders. The forces applied along the frame bottom are linked by straps, which are flexibly joined at the frame bottom (figs. 6 and 7) and applied as a concentrated force along the line of symmetry of the frame. For this purpose the arrangement of figure 8, consisting of oil-pressure cylinder and lever system, is employed.

Obviously the lines of action of all forces must be located in the plane of the frame web. Unavoidable eccentricities must be equalized by guides. A much simpler set-up is shown in figure 9, but the strength data obtained with it are a little too high, and considerable error may occur on closed frames. Hence it is only rarely used.

III. Comparison of Strength and Weight of Different Frame Forms

The data from various tests with different frame designs have been collected in figure 10. The figures themselves are indicative of the minor differences in quality existing between the different designs. Particular advantages accruing from the shape of the bottom girder are therefore hardly to be expected. Obviously, errors, such as unfavorable location of the cut-outs and adverse diffusion of load should be avoided. On dividing the absorbed bottom load by the weight of the fframe, it is found that a load of from 1.7 to 1.9 t per kilogram of frame weight is taken up. In one instance only is the load capacity less, 1.4, in two cases higher, 2.2 and 2.3 t. Figures 11 and 12 illustrate some of the examined frame designs.

IV. Breaking Tests with Floats

The aim here is to prove the strength for all possible load cases with a limited number of tests. This is accomplished by first plotting the moment curves and the cross stress curves for all these loading conditions. Then the curved surface line to the two sets of curves is drawn and a load distribution is provided which takes both the moment and the cross stress enveloping curve into account. In this manner the number of load tests can be reduced to the three cases: nose impact, stern impact, and step impact.

a) Nose Impact

Figure 13 illustrates the experimental set-up. The float is joined at the nose to the test column. The moment is applied by a pair of oil-pressure cylinders.

b) Stern Impact

The set-up is practically the same as in the preceding case, except that the other end of the float is clamped to the test column.

c) Step Impact

The experimental arrangement is shown in figure 14. The float is held by anchor bolts at the two points of attachment. The load is applied at the individual frames by means of cradles. A system of levers combines the individual forces into one force. The load is again applied by a pair of oil-pressure cylinders mounted at either side of the float.

d) Results of Tests

The described experiments involved a float with especially low unit weight. On such small dimensional parts it is essential that the areas of pronounced local sagging, which might induce premature failure, be continuously observed during the test. If such places are noticed, the test should be interrupted and the areas strengthened, as by joining the stringer sections to the frame by means of riveted angles, for instance. Such comparatively rapid alterations make it possible to avoid unnecessary labor at the point where no previous clarity exists about the necessity of junction and stiffener plates, and assure a particularly light construction of adequate strength. Subsequent to the corresponding small reinforcements the required 1.55 times safe load is applied and hence the strength of the float proved.

Important for the construction are the stresses applied in the test. The maximum longitudinal stress in the case of stern impact occurs at the rear joint. Here the compressive stress in the covering amounts to 1900 kilograms per square centimeter. In the case of nose impact the maximum longitudinal stress is located at the front junction. The ultimate stress of the skin amounted to 1200 kilograms per square centimeter pressure. The maximum shearing stress in the case of step impact occurs at frame 11. A shearing stress of 560 kilograms per square centimeter was reached without inducing failure. The loading was not continued to failure, since the float was intended for other tests in connection with the airframe.

V. Tests with Float Systems

This test involves the float with the flotation gear.

Since fuselage and wings of the airplane had been destroyed in previous load tests the float supports were mounted on a specially designed framework. Figures 15 and 16 illustrate the experimental arrangement. The flotation gear was inverted and attached to a beam B pivoted in A. The lateral bracing consisted of a cross beam C solidly connected with B. The dissimilar rigidity of beam C from the wing of the airplane conditioned several changes in the cable braces from these prescribed for the completely mounted machine. These modifications, however, are not important.

The loading of the flotation gear for centrically applied forces is effected by means of oil pressure. Oil cylinders F, attached by means of special cages E 4 to rail D anchored to the floor, exert a downward pressure, the cylinders acting over 1 set of levers G each on beams H placed over the float frames. For the torque provided in some of the loadings the end frames of the float carry riveted beams J at the ends of which moments are applied by means of weights. The load applied by the oil pressure is checked by a dynamometer suspended at point K of beam B pivoted in A. This check was possible in the symmetrical load cases only, in unsymmetrical load cases the beams B and C were fixed toward the floor in order to prevent overturning of whole unit.

The tests themselves fell into three groups:

A) Investigation of the extent to which the assumption serving as basis of the calculation holds true in that the float bodies can be regarded as being rigid, that is, their form changes remain so small that they become negligible in the solution of the indeterminate system. To this end the form changes at the attachment points are recorded under torsional and bending stresses.

B) For the many load cases to be verified the stress distribution was measured on cables and struts. The tensile stresses in the cables and the compressive and bending stresses as well as the shape of the deflection curve of the struts were recorded with tensometers. The loading was raised considerably beyond the sare load to the vicinity of the breaking point. This, of course, occasioned form changes which somewhat detract from the behavior in the subsequent tests. – In this manner the stresses in cables and struts under theoretical breaking load are established.

C) Breaking tests afforded the breaking load of the struts under the beam-column stress which occurs. Since some of the cables were dimensioned as high as the struts, they were replaced by the next heavier size before the breaking test as cable failure was, of course, to be avoided. The ultimate load of the endangered cables was established separately by tensile test.

a) Measurements

a) Check on load by dynamomenter

b) Twisting on float body

c) Angle of twist at end of forward starboard strut by goniometer and plumb line

d) Deflection of float bodies

e) Deflection of struts

f) Stresses in struts; 4 tensometers each at starboard struts, center and (float) end; 2 each at beginning (body end), or altogether 10 tensometers per strut (The portside struts generally carry only 2 tensometers each.)

g) Stresses in the cables with 1 tensometer each

h) Shock absorption of flotation gear by distance tape on floats and flotation gear – Measurement by leveling gage.

The dimensions of the struts and cables at the individual test points, the actual E modulus, and the strength values of the material also must be determined.

The compilation in figure 17 summarizes the individual test series:

Load = below the keel

Load and torque = load shifted laterally

As regards the supplementary tests it should be noted that these tests were made for the purpose of ascertaining the strength of the rear struts which do not break under the specified loading conditions. The eccentric loading was chosen in the latter case to prevent a second failure of the rear starboard strut.

b) Results

1. The float bodies are practically rigid in torsion. Respecting the absorption of torque by the flexurally stiff adjoining strut, it is immaterial whether the torque is applied at the forward or rear end of the float (equal stress curves).

2. Breaking load = 4700 kilograms/float in the case of symmetrical step impact. Energy consumption 40 mkg under 700 kilograms loading on the total flotation gear proceeding approximately squared with the stress. Referred to ultimate load, it affords 71 mkg (for a gross weight of 2.2 t).

VI. Tests with Air Frame and Flotation Gear

In the following an experimental set-up is described as used for the static testing of air frame and flotation gear in the case of eccentric bow impact, that is, setting down on one float (figs. 18 and 19).

The weight of the air frame was balanced at wing center by means of weights and at the frame A by dynamometer and a set of pulleys. The portside float stub was lengthened by a substitute frame. The moment about the longitudinal axis applied to the air frame by the portside float was taken on the upper and lower wing, and, in adtition, by moments with force applied at the starboard float and portside cabane fitting and by a twisting moment at a frame. The moment about the lateral axis and the cross-wind force were chiefly taken at the forebody.

There were 16 loading areas in all (exclusive of the weight equalization). The 10 higher loads were applied by oil pressure, 5 by weights; whereas 1 moment was applied by pulleys and dynamometer. The forces 6600 and 1080 kilograms are the external forces, all others are reaction forces and moments. The load is applied in single stages. Since the specified safe load factor of the float is only 1.55, the float-support struts were strengthened at the higher load stages. Then the load was raised to 1.8, and the strength of the air frame for this loading condition herewith proved.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.

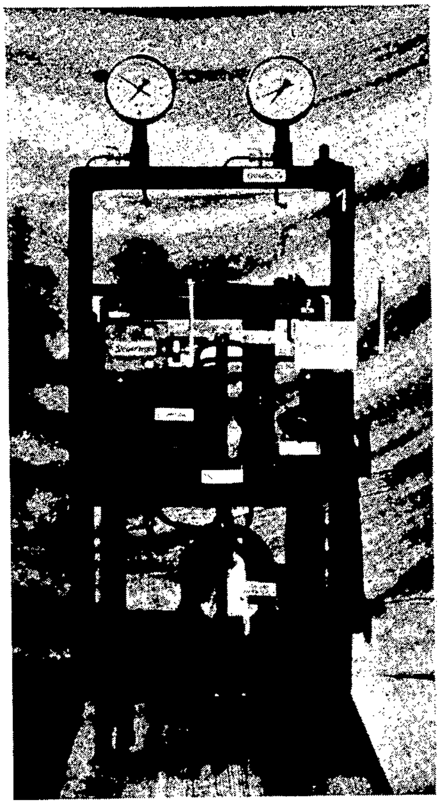


Figure 1a.- Portable oil pressure pump with controls and test instruments for two oil circuits.

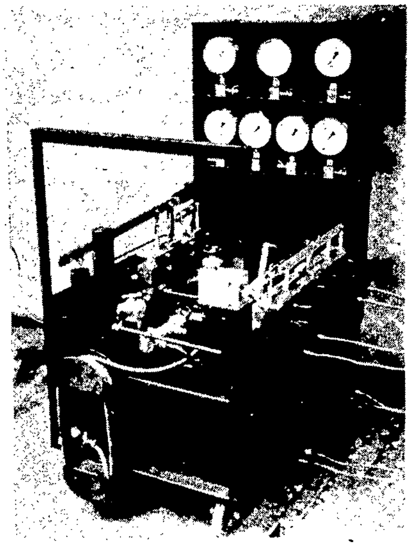


Figure 1b. Control apparatus for automatic oil pressure distribution of six oil circuits.

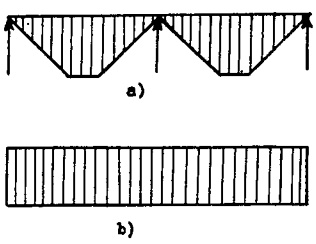


Figure 2.- (a)Mathematical bottom pressure distribution on the float frame. (b)Experimentally applied bottom pressure distribution.

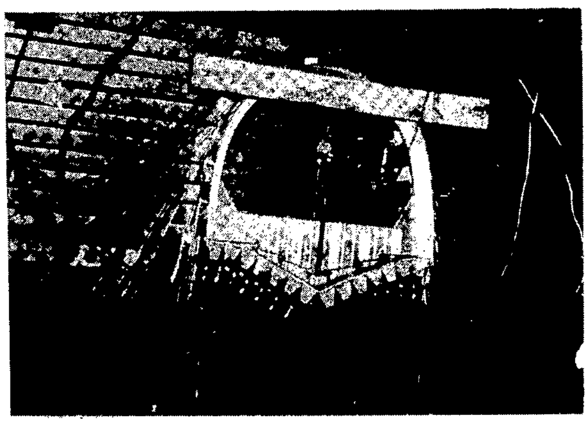


Figure 3.- Disposition of a frame on the test board.

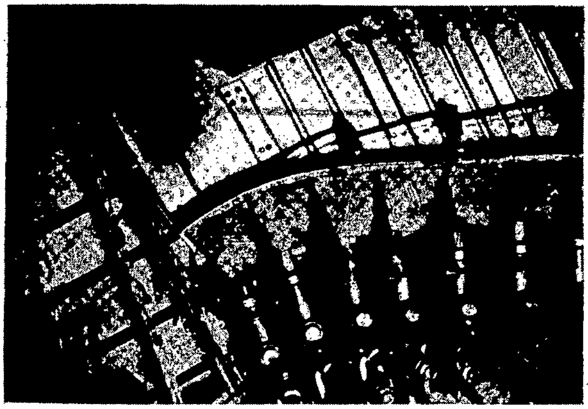


Figure 4.- Distribution of pressure over the frame.

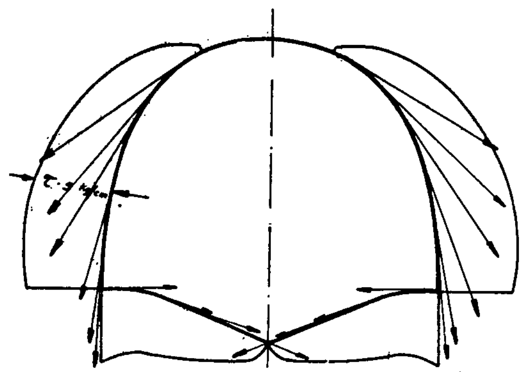


Figure 5.- Shear distribution over the frame and analysis in five concentrated loads.

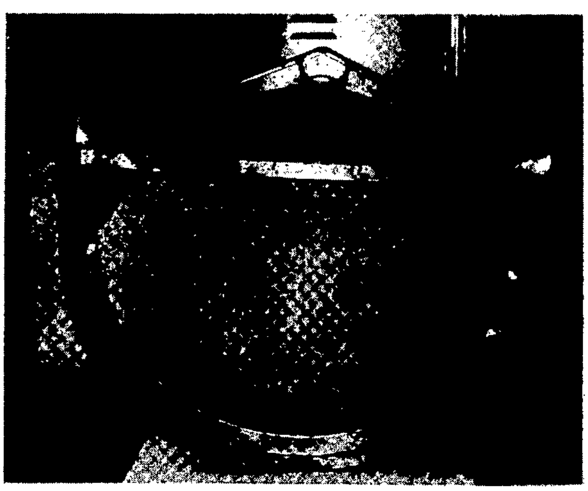


Figure 6.- Application of forces acting along frame bottom by flexibly attached straps.

Figure 7.- Different version of strap fitting according to fig. 6.

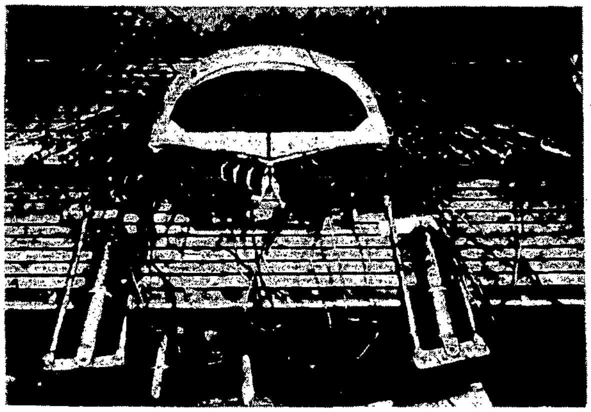


Figure 8.- Application of complementary force at the straps.

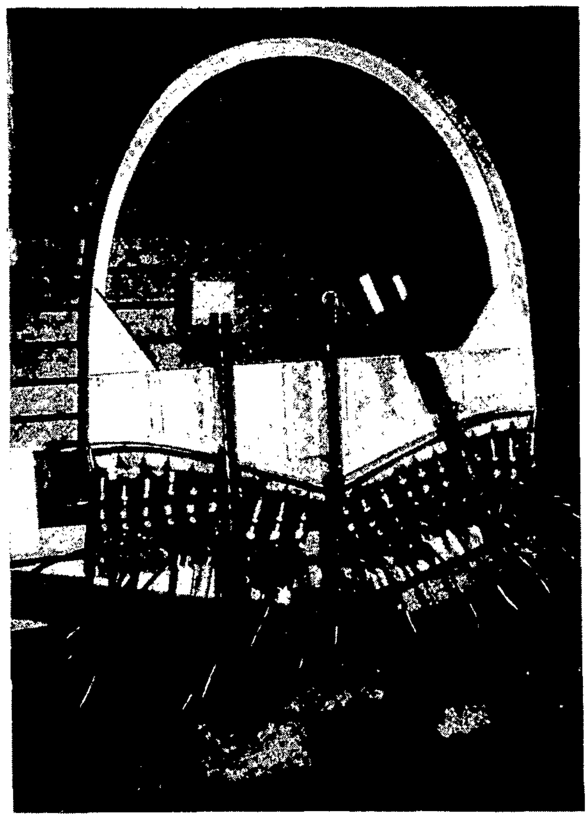


Figure 9.- Simple test rig for frames which generally give too high values and is therfore rarely used.

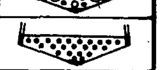
Width of frame mm	Web Height mm	Web Thickness mm	Weight kg	Ultimate load t	Bottom pressure at failure kg/cm	Design
830	240	0,5	0,84	1,89	21,6	
980	270	0,5	2,90	3,92	39,5	
1220	308	1,5	1,65	3,55	29,6	
1220	310	1,2	1,50	2,66	22,2	
1220	310	1,2	1,60	2,66	22,2	
1220	310	0,5	1,70	3,11	25,9	
1280	350	2,0	2,50	4,83	35,7	
1260	350	1,8	2,25	4,26	31,6	
1260	350	2,0	2,50	4,26	31,6	
1280'	350	2,0	2,25	4,26	31,6	
1280	350	1,5	2,20	3,97	29,4	

Figure 10.- Strength of different frame designs.

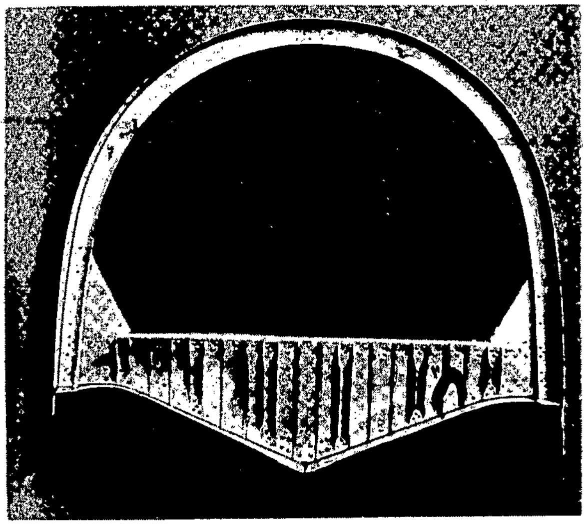


Figure 11.- View of explored frame designs.

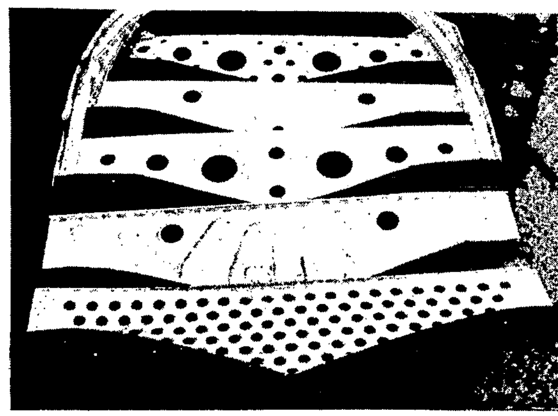


Figure 12.- View of explored frame designs.

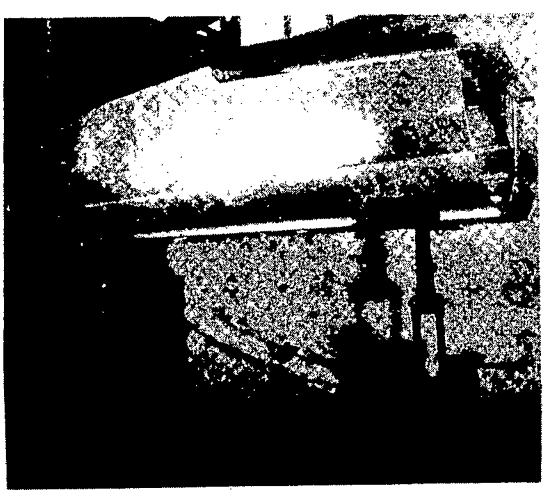


Figure 13.— Strength test of float in the case of bow impact.

Figure 16. Arrangement for testing the strength of a flotation gear.

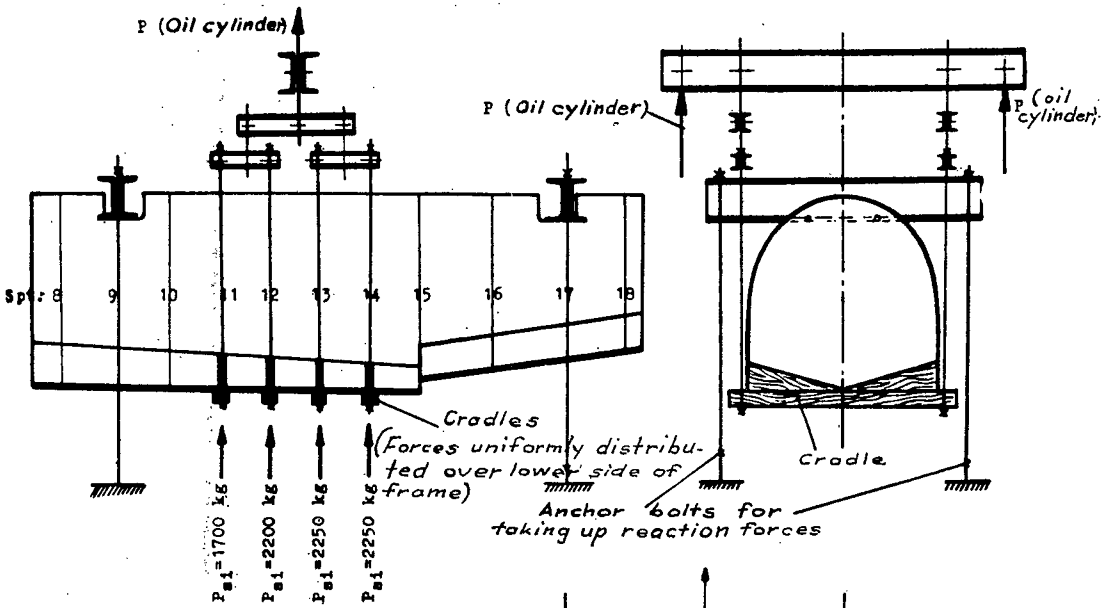


Figure 14.- Experimental setup for testing float under step impact.

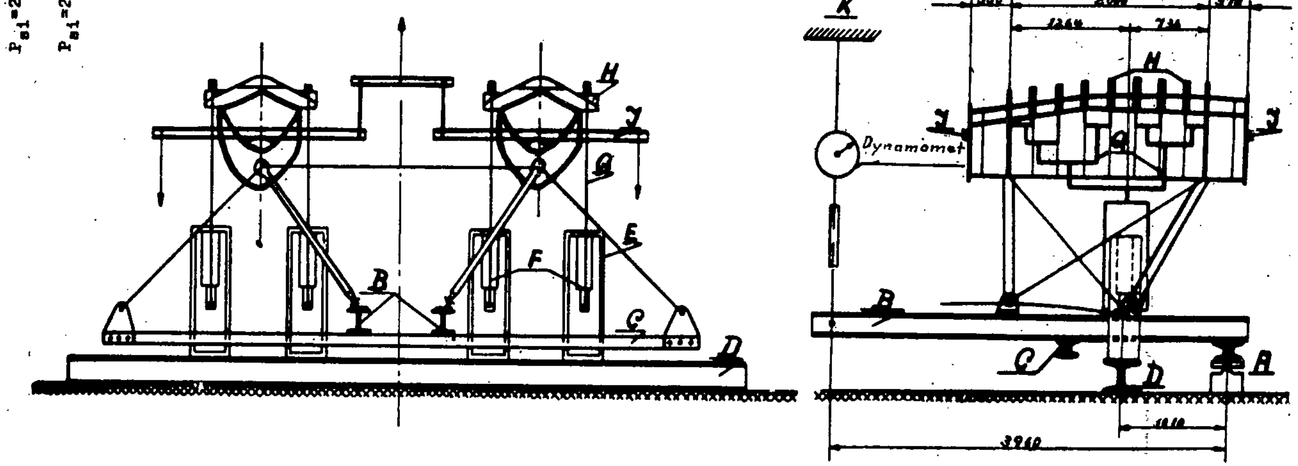
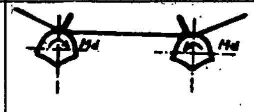
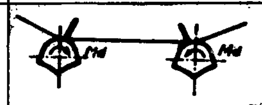
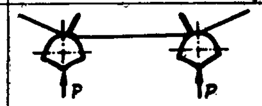
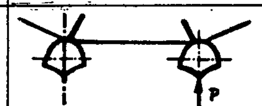
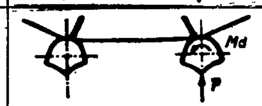
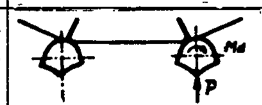
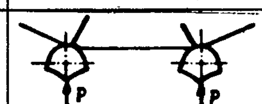
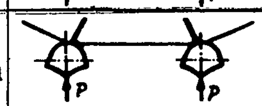
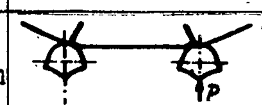


Figure 15.- Diagrammatic sketch of experimental layout for testing the strength of float supports.

	Type of load	Load pattern	Loaded to	Notes,
Pure torque	Torque at front end frame.		$M_d = 320$ mkg	Twisting measurement at floats
	Torque at rear end frame.		$M_d = 320$ mkg	
Symmetric loading	Symmetrical step impact.		$P = 4500$ kg	Stress measurements for determining load distribution over struts. Measurements at several load stages to 1.5 times safe load.
Eccentric loading	Eccentric step impact.		$P = 3700$ kg	
	Eccentric laterally shifted step impact outward.		$P = 1200$ kg $M_d = 240$ mkg	
	Eccentric laterally shifted step impact inward.		$P = 1500$ kg $M_d = 300$ mkg	
Symmetric loading	Symmetrical step impact.		$P = 4700$ kg	Loading to failure. Front strut collapsed.
Symmetric loading	Symmetrical step impact shifted 40 cm rearward.		$P = 4300$ kg	Supplementary test, rear struts loaded to failure. Rear starboard strut breaks.
Eccentric loading	Eccentric step impact shifted 40 cm rearward		($P = 3900$ kg)	Loading to failure of rear port-side strut.

Outline of 16 individual test series.

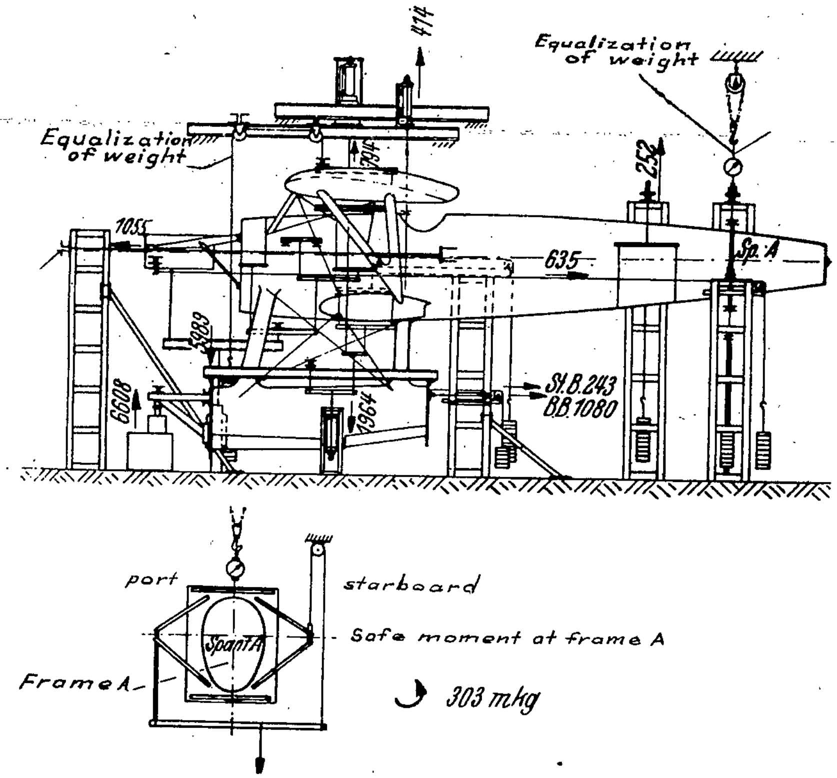


Figure 18

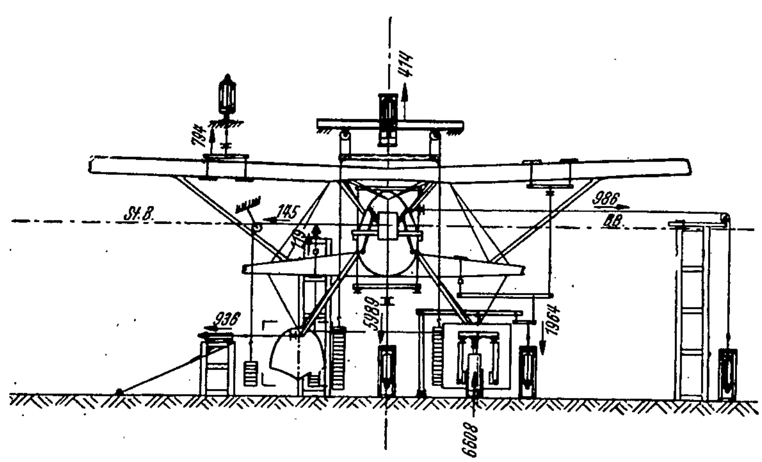


Figure 19

Figures 18 and 19.- Test arrangement for checking strength of airframe and floatation gear under eccentric step impact, i.e., setting down on one float.